CLINICAL APPLICATIONS AND OUTCOMES OF USING INDICATORS OF RISK IN CARIES MANAGEMENT

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ABSTRACT:

The aim of this review was to systematically assess clinical evidence in the literature to determine the predictive validity of currently available multivariate caries risk-assessment strategies [including environmental, sociodemographic, behavioral, microbiological, dietary/nutritional, and/or salivary risk factors] in: 1) primary teeth; 2) coronal surfaces of permanent teeth (referred to as permanent teeth); and 3) root surfaces of permanent teeth (referred to as root surfaces). 1249 articles were identified in the search, and 169 were selected for full review. Inclusion and exclusion criteria were established prior to commencement of the literature search. Papers that conformed to these criteria, and reported a predictive outcome for the model were included (n = 15 for primary teeth; n = 22 for permanent teeth; and n = 6 for root surfaces), and 126 papers were excluded. Included articles were grouped by study design as: longitudinal, retrospective and cross-sectional. The predictive validity of the models reviewed depended strongly on the caries prevalence and characteristics of the population for which they were designed. In many instances, the use of a single predictor gave equally good results as the use of a combination of predictors. Previous caries experience was an important predictor for all tooth types.

Key words: Dental caries, predictive validity, multivariate risk assessment

INTRODUCTION:

There is an increasing interest in evidence-based treatment in dentistry, echoing similar trends in medicine. The intention of this approach is to base patient treatment decisions on a combined use of current best evidence and individual clinical expertise. Risk assessment must be considered a necessary component in the clinical decision making process. Caries risk indicators may be useful in the clinical management of dental caries by helping dental professionals to: determine if additional diagnostic procedures are required; identify patients who require caries control measures; assess the impact of caries control measures; guide in treatment planning decisions; and determine the timing of recall appointments. In the context of this paper, “caries risk indicators” were defined as variables that are currently thought to both cause the disease (e.g., microflora) and, although being not etiologic for the disease, have shown to be useful to predict it (e.g., socioeconomic status). In contrast, Beck (1990) defined the causative variables as “risk factors”, and the non-etiologic variables as “risk indicators”. While there has been a high level of interest in identifying risk indicators, to date only a few studies have attempted to determine how the application of risk indicators in dental practice impacts on dental health outcomes (Brambillaa et al., 1999; Hausen et al., 2000). Other papers at this conference have reviewed the individual risk indicators. This systematic review will focus on studies evaluating the degree to which various combinations of risk indicators can predict dental caries (i.e., predictive validity of the test) in primary and permanent teeth.

Multifactorial modeling has attempted to prove its value in longitudinal caries prediction studies by showing the interrelations and interactions of risk indicators with the occurrence of the disease. Beck et al. (1988) indicated that, for the success of a caries risk-assessment model, one or more social, behavioral, microbiologic, environmental or clinical variable(s) should be included. This is attributed to the multiplicity of factors that influence dental caries. Modeling has usually been based on a dichotomized dependent variable, either as "no" versus "some" caries increment (Beck et al., 1992); or with specified cut-off points in populations with high caries incidence (Abernathy et al., 1987). The sensitivity and/or specificity of models has rarely been 80%, considered to be the minimum target level for screening purposes. Stamm et al. (1988) had suggested that: "To be useful, a working [caries prediction] model should produce a sensitivity of 0.75 or higher and specificity level of at least 0.85". Therefore, it has been suggested that a risk model should have a combined sensitivity and specificity of at least 160% to make a good diagnostic test (Kingman, 1990).

The aim of this review was to systematically assess the clinical evidence to determine the predictive validity of currently available multivariate caries risk-assessment strategies in: 1) primary teeth; 2) coronal surfaces of permanent teeth (referred to as permanent teeth); and 3) root surfaces of permanent teeth (referred to as root surfaces). The intent was to be able to determine "what are the best (combination of) indicators for an increased risk of dental caries?", which was one of the questions (#2) developed by the planning committee of the National Institutes of Health Consensus Development Conference: Diagnosis and Management of Dental Caries throughout Life to be addressed by the Consensus Development Conference panel. This, in turn, should help establish "how clinical decisions regarding prevention and/or treatment should be affected by detection methods and risk assessment?" (Question #5).

METHODS:

Search Strategy:

A literature search of publications dating from 1980, in two databases: MEDLINE (OVID) and EMBASE, was conducted. Only English language publications concerning humans were included in the search strategy. It is known, that electronic databases often retrieve only a portion of the relevant articles because of inaccurate indexing. To help identify as many papers as possible, key word headings were created. The key word headings included in our search were:

For primary teeth: [(Caries AND Risk hedge) AND Diagnosis hedge/limited to human, English, 1980+] AND (age group limit OR primary dentition hedge).

For root surfaces: [(Caries AND Risk hedge) AND Diagnosis hedge/limited to human, English, 1980+] NOT (age group limit OR primary dentition hedge) AND root caries hedge.

For all other dentition (i.e., permanent): [(Caries AND Risk hedge) AND Diagnosis hedge/limited to human, English, 1980+] NOT [(age group limit OR primary dentition hedge) OR root caries hedge].

Due to the volume of references obtained in the electronic search (n = 1249), it was decided that secondary hand searching would not be feasible and, therefore it was not done.

Selection Criteria:

Inclusion and exclusion criteria for the papers selected for review were established prior to commencement of the literature search. The inclusion criteria included: 1) the use of more than one type of caries risk indicator category used to calculate the predictive outcome [past disease experience; microbiological factors, host factors (e.g., salivary buffer capacity and salivary flow rate; tooth morphology), and others (e.g., diet, sociodemographic factors, age, sex, race, fluoride exposure, oral hygiene)]; 2) the presence of a clear prediction outcome (predictive validity: e.g., sensitivity, specificity, positive predictive value, negative predictive value). It was decided for the purposes of this systematic review to include only articles that reported sensitivities and specificities derived from testing of multivariate models, thus permitting direct comparison of the prediction outcomes from the selected articles. Every included article was listed. Excluded articles were reported too. Additionally, the following articles were excluded from full review: reviews, *in vitro* studies, research related to population-based approaches rather than individual approaches, and papers not related to dentistry. Except for review papers, these were not listed in the exclusion table.

Data Collection and Analysis:

Two of the reviewers (DZ, MF) conducted an initial review of all 1249 identified articles by title and abstract. If both reviewers agreed that an article should be included, then the article was included. If they disagreed, then they discussed the reasons for disagreement. If no agreement was reached, then the primary reviewer (DZ) made the final decision. Before sorting through all the articles, 50 articles were used to test the inclusion criteria. Once all articles had been sorted out into included, excluded, and questionable (a decision could not be made based on the abstract). For included/questionable articles, the whole article was read by one of the reviewers (MF or AL), and information was added to the appropriate evidence table. As before, 10 included articles were initially used to test the evidence table prior to inclusion of all the selected articles. The two reviewers who added data to the tables were cross-calibrated by reading several articles and checking each other’s decisions. Once the tables were completed, all the references were checked one more time by one of the reviewers (MF) and final changes/adjustments were made. The primary reviewer (DZ) rechecked blindly those articles where there had been a change in status: from originally included based on the abstract, to excluded once the whole article was obtained or vice versa. He then reviewed the papers independently and decided if they were to be included or not. If there was disagreement, then the article was discussed by the reviewers. If no agreement could be reached, then the primary author would make the final decision. Once all the articles had been included into tables, the information from inclusion tables was checked for accuracy.

Once the articles had been sorted out, a list of included and excluded articles for each category (primary teeth, permanent teeth and root surfaces) was prepared. 169 papers were added either to the inclusion or exclusion tables. 169 papers were selected for full review, and the complete publications were obtained. Papers that conformed to the selection criteria, and reported a predictive outcome for the model were included (n = 15 for primary teeth; n = 22 for permanent teeth; and n = 6 for root surfaces). Tabulation of excluded articles (n = 126; Table 4) included the reason for exclusion (i.e., lack of more than one risk indicator, no outcome data, etc). Three evidence tables were prepared: caries risk prediction for primary teeth (Table 1), caries risk prediction for permanent teeth (Table 2), and caries risk prediction for root surfaces (Table 3). Articles reporting information on more than one type of caries were included in more than one table. Included articles were additionally grouped by study design as: longitudinal, retrospective and cross-sectional. Additionally, articles on caries prediction for permanent teeth were also grouped in those done in children and those done in adults. The following is the list of the criteria included in the tables to assess the papers: authors and year of publication; sample size (n), and number of subjects in each group; age of sample at study initiation; study design (e.g., cross-sectional; longitudinal; retrospective); risk indicators analyzed: past caries experience (e.g., sound or carious teeth; cavitated or white spot lesions, etc.); microbiological risk indicators (e.g., mutans streptococci; lactobacilli; candida; visible plaque); host related risk indicators (e.g., tooth morphology; salivary flow rate; salivary buffer capacity; gingivitis, etc); other risk indicators (e.g., age; sex; race; diet; hygiene; medication use; socioeconomic status; fluoride exposure, etc.); outcome or dependent variable (e.g., caries increment at the end of the study); sensitivity; specificity; baseline caries scores; criteria used to determine high risk; method of modeling used (e.g., logistic regression analysis; logistic discriminant analysis, etc.); source of sample and country; sampling method; training of examiners; reliability of examiners; blinding of examiners; blinding of patients; attrition rate: number of lost subjects (withdrawals, non-responders); conclusion reported by authors.

All included articles were systematically assessed for their validity. Since evidence is considered best obtained from randomized longitudinal studies, these were the studies given the highest validity in our review. Included studies for all types (longitudinal, retrospective and cross-sectional) were graded in 3 categories: “good” (≥ 3of the following categories reported), “fair” (2 categories reported) and “poor” (≤1 category reported) depending on the amount of information provided in the publication to support the methodology used to obtain their results. The main variables assessed for this purpose were: 1) whether the study reported how samples were obtained (i.e., method of sampling), 2) whether examiners’ training/calibration was reported, 3) whether the examiners’ reliability was reported, and 4) whether examiners and/or patients were blinded during the study.

RESULTS:

Of the 15 included articles to predict caries in primary teeth: 10 articles were longitudinal studies (2 rated as good), and 5 articles were cross-sectional studies (1 rated as good). The permanent teeth articles were separated into those used to predict caries in children/adolescents (< 20 year olds) and those used to predict caries in adults. Of the 18 permanent teeth articles in children/adolescents: 13 were longitudinal studies (2 rated as good), 2 were retrospective studies, and 3 were cross-sectional studies (1 rated as good). Of the total of 4 permanent teeth articles in adults: 2 were longitudinal studies (1 rated as good), and 2 articles were cross-sectional studies (1 rated as good). Additionally, for root surfaces, 6 articles were found: 5 of these concerned longitudinal studies, and 1 cross-sectional study. None of these were rated as good. All these models included some aspect of past caries experience as a predictor. The second most frequent predictor included in all these models was the category of "other variables", probably due to the large amount of variables included here. The third most frequent predictor included for primary and permanent teeth caries prediction was "microflora", followed in last place by "host factors". In the case of root surface caries prediction the "host factors" category was more frequently used than the "microbiology" category.

Of all the models reviewed, none of the longitudinal studies graded as "good" had a combined sensitivity and specificity in excess of 160%, although the model reported by Demers et al. (1992) was very close (159%). These authors concluded that previous caries experience was the strongest predictor in their model, followed by parent's education. Additionally, for primary teeth, there was one "fair" study in which combined sensitivities and specificities summed 170%

(Holst et al., 1997) – using 1 year olds, followed for 2 years, and using all categories of risk assessment factors (with visible plaque, deep fissures and oral hygiene being the strongest predictors). Several longitudinal studies (e.g., Leverett et al., 1993b; Steiner et al., 1992), classified as "poor", only because of the lack of reporting of the above mentioned criteria, did reach combined sensitivities and specificities of 160% or more. Several cross-sectional studies also reached this value (e.g., al Ghanim et al., 1998; Leverett et al., 1993a).

DISCUSSION:

A systematic review is an objective summary of the findings from all known, well-conducted, clinical investigations on the subject in question. The rationale is that the same scientific principles of objectivity that are applied to the conduct of primary research are also applied to a review of that research. In clinical research, randomized longitudinal studies are considered to be the "gold standard" from which evidence can be obtained. In this type of study we can follow individuals over time and assess disease incidence, rather than only prevalence, to allow for correct classification of the caries risk assessment prediction results. Therefore, this was what we used as a "gold standard" in the analysis of the results of this systematic review. Cross-sectional studies that met the inclusion criteria were added to this review, even though measurements are made only at one point in time. Clinical or statistical associations noted in this type of study should be followed up with a longitudinal study to test hypotheses on the relationship between, for example, caries risk indicators to the disease in question (i.e., dental caries).

Furthermore, the use of a test that measures a factor that causes dental caries (e.g., microorganisms) or contributes to the development of the disease (e.g., low salivary flow rate) in a caries risk assessment model should be carefully analyzed. There is a great difference between the use of a test to measure *Streptococcus mutans* in saliva to assess the presence of the disease at one point of time (diagnosis of caries prevalence) and using that same test to predict the appearance or progression of disease in the future (prediction of caries incidence). This is another reason why careful examination of the type of study (cross-sectional vs. longitudinal) done to validate a risk indicator should be taken into consideration when analyzing the results of available evidence.

Since the purpose of this review was to assess the validity of multifactorial test models for caries prediction, we decided that in order to be included, articles had to use more than one category of risk indicators (e.g., previous caries experience, microbiological data, etc) and had to provide some measure of the reliability of the test. Since the articles reviewed provided sensitivity and specificity, these were the data we used for comparison purposes. We would have preferred to use reported positive and negative predictive values for comparison purposes, since these take into account the prevalence of caries in the sample, but these data were not commonly available in the articles. We decided to exclude articles that reported only odds ratio as a measure of relative risk. Odds ratios are good indicators of risk from case-control studies for individual variables, but cannot assess the predictive validity of a test, because they do not consider the incidence of the disease (i.e., change over time).

The importance of the score for sensitivity and specificity should be based on consideration of the relative consequences of having too many false positives or false negatives. If the caries risk assessment test is to be used for mass-screenings or at the public health level, it may be more desirable to have a high specificity in order not to overburden the health care delivery system with too many false-positives, which would result in over treatment of individuals with preventive approaches and, therefore, over use of limited resources. However, at an individual level, it might be desirable, both from an ethical and economical perspective, to increase the sensitivity of the predictive test in order to reduce the number of false negatives. Failure to identify these individuals correctly as being at risk for caries, may result in need for more advanced/costly/painful therapy in the long term, due to the presence/ progression of the disease. On the other hand, by increasing the sensitivity of the risk assessment test, the number of false-positives would increase, but if the dentist uses a preventive management strategy this would not result in any harm to the patient (since the disease would not be present nor allowed to progress), other than economical (cost of prevention). Therefore, Kingman's (1990) statement that a risk model should have a combined sensitivity and specificity of at least 160% (which implies a high sensitivity and specificity) to make a good test are applicable to private practice, regardless of the possible costs of over-treating some individuals with caries preventive approaches that do not need it. This combined value of 160% was the gold standard that we used when we analyzed the results of this systematic review.

Additionally, articles that reported information to support the methodology used to obtain their results were given the highest score (good). The score of good, fair and poor given to all studies was only based on these criteria, and did not imply that the study was poorly conducted. It only rewarded studies that published this type of data. While most of the longitudinal studies in this systematic review were not controlled clinical trials, blinding of examiners and patients regarding the patient's initial tests and risk status results was deemed important from a research design perspective. It is likely that an individual identified initially as high caries risk might be more motivated to take care of his/her teeth or might receive a more careful assessment by the examiner than individuals deemed at lower risk.

The usefulness and practicality of clinical variables and non-clinical variables that are easily attainable through routine clinical examinations (e.g., number of sound and carious teeth; socioeconomic status, etc.) vs. non-clinical parameters that need to be specifically measured for risk assessment purposes (e.g., number of *Streptococcus mutans* in saliva; buffer capacity of saliva, etc.) needs to be carefully analyzed when considering a test for clinical use. Stamm et al. (1988) suggested that “It is recognized that any model, regardless of its ultimate accuracy, would have to be based on a data collection system that is relatively quick, inexpensive, and requires a limited armamentarium, and be acceptable to those to whom it is applied”. Data from our best level of evidence (“good”) for caries prediction in primary teeth concluded that previous caries experience was the best predictor, followed by parent’s education (Demers et al., 1992) and socioeconomic status (Isokangas et al., 1992). For permanent teeth in children and adolescents, an article rated as “good” concluded that clinical predictors (DMFS, predicted caries by the clinician, and pit and fissure morphology) were again the most important indicators, while the other factors contributed little to the prediction (Disney et al., 1992b). For “good” articles on permanent teeth in adults, results showed that non-clinical factors, such as education and marital status, showed significant effects, since both of these factors may influence attitudes towards oral health; and that the baseline number of teeth and mean periodontal attachment loss may predict the number of tooth surfaces at risk of decay (Hawkins et al., 1997). These data support the conclusion that clinicians can predict risk using only variables easily available at periodic examinations, since the best indicators of caries risk are easily obtained from dental charts and do not require additional testing.

Most of the studies of risk assessment models covered by this review have been conducted under clinical trial conditions. Risk assessment approaches must ultimately be validated in the private practice setting and must be considered useful by the dental practitioner if they are to have their intended benefit (Moss and Zero, 1995). Furthermore, when applying Fryback and Thornbury's (1991) six levels for assessing the clinical usefulness of information from new diagnostic technology to caries risk assessment, it is clear that we have a long way to go before we truly understand its clinical usefulness at a health outcome level and cost benefit level. Given the complexity and unevenness of clinical judgments in applying caries risk assessment to the clinical management of the caries process (Disney et al., 1992b; Alanen et al., 1994; Saemundsson et al., 1997), the use of expert decision-support systems has been advocated (Anusavice, 1998; Benn et al., 1999). However, these systems must also be validated for their clinical usefulness.

SUMMARY

Based on this systemic review the following conclusions were reached:

- The predictive validities of the models reviewed depended strongly on the caries prevalence and characteristics of the population for which they were designed.
- Many models included similar categories of risk indicators but provided very different outcomes depending on the study population.

- In many instances, the use of a single risk indicator gave equally good results as the use of a combination of indicators.
- No combination of risk indicators was consistently considered a good predictor when applied to different populations, across different age groups. However, in general, the best indicators of caries risk were easily obtained from dental charts and did not require additional testing.
- Previous caries experience was an important predictor in most models tested for primary, permanent and root surface caries.
- None of the randomized longitudinal studies conducted to predict root surface caries were rated as “good”.
- The desired combination of sensitivity and specificity (>160%) was only achieved in a few cases.
- Using the highest level of evidence collected, none of the studies rated as “good” reached this combined level of sensitivity + specificity.
- Most of the research in this area has been done in children, for either primary or permanent teeth.

RECOMMENDATIONS

Clearly there is the need for further research to identify and validate caries risk assessment strategies that can be applied in dental practice, especially for adults. More importantly, studies are required to establish whether identification of high-risk individuals can lead to more effective long-term patient management that prevents caries initiation and arrests or reverses the progression of carious lesions. Another recommendation follows from the consistent finding that past caries experience is a strong predictor of future disease. Most studies have used the DMFS (decayed, missing, filled surfaces) index to determine past caries experience, and many investigators don't report the necessary information to separate out the "D" (decayed) component from the "F" (filled) component. Most studies do not report the presence of non-cavitated lesions, which have been show to have predictive value (Koch and Krasse, 1979; Steiner et al., 1992). Furthermore, the DMFS index does not establish if any of the decayed lesions are active (progressing) or inactive (arrested). The presence of caries activity (active and progressing demineralization) should be a much stronger predictor of developing future carious lesions (frank cavitations) than using the DMFS index. Currently, determination of caries activity is made based on subjective assessment of the appearance and physical properties of tooth surfaces affected. The development of technology to detect and quantify early caries lesions and to directly assess caries lesion status (active vs. inactive) may prove to be the best way to identify patients that require intensive preventive intervention.

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TABLE 1. Inclusion Table – Primary Teeth

Researcher Rating	n	Age at onset	Study Design	Variables: Past Caries or Disease Experience	Variables: Microflora	Variables: Host	Variables: Other	Outcome=Validation criteria=true disease	Sensitivity	Specificity	Combined Sens + Spec
Longitudinal studies											
Demers et al., 1992 Good	302	5 year olds	Longitudinal (1 year)	**Caries experience: dmfs=0 or dmfs>0 (WHO, no radiographs)**	SM, **LB (Bactotest)**	Buffer capacity	Age, sex, parent's education, family structure, fluoride consumption, oral hygiene (debris index)	≥1 ds (Mean dfs increment: 2.1 ± 3.6)	81.8% 78.3% (for caries experience only)	77.4% 77.4% (for caries experience only)	159 155
Holbrook et al., 1993 Poor	158	4 years	Longitudinal (2 years)	DMFS, dmfs	**MS, LB**	Salivary pH, buffer capacity, flow rate	**Sugar misuse; Pediatric medicine frequency of consumption; use of fluoride tablets**	Caries increment (dmfs) (Actual data NR)	80% (not counting past caries experience) For caries experience only: 91% (caries present), 98% (caries free)	78% 61% (caries present) 82% (caries-free).	158 152 180
Holst & Braune 1994 Poor	102	1 year olds	Longitudinal (3 years)	dfs (manifest lesions); incipient lesion not present	Not used	Not used	Health status and medication; **eating habits (bottle at bedtime)**; **oral hygiene**; use of fluorides; parent's knowledge of decay; parent's interest	≥4 deft ≥8 defs (No caries by age 4: 81.4% (n =83); n =19 children with caries: 3.9% ≥4 deft; 2% ≥8 defs)	58% (by age 3) 42% (by age 2) with variables, when caries experience was 0: 27%	99% (by age 3) 100% (by age 2) with variables when caries experience was 0: 100%	157 142 127
Holst, Martensson et al. 1997 Fair	102	1 year olds	Longitudinal (2 years).	Visible caries	**Visible plaque**	**Deep fissures in the molars**	Illness; saliva affecting medication use; eating habits; **oral hygiene frequency**; fluoride use	Any caries at 4 years (Actual data not included)	100% (risk assessed at 2, caries at 4)	70%	170
Isokangas et al., 1993 Good	297 (3-4 year olds)	3-4	Longitudinal (1 year)	Caries, **Predicted caries**	Not used	Not used	Socio-demographic	≤1 dentinal caries lesion in need of restoration (actual data NR)	3-4 year olds: 45%	3-4 year olds: 92%	137

Researcher Rating	n	Age at onset	Study Design	Variables: Past Caries or Disease Experience	Variables: Microflora	Variables: Host	Variables: Other	Outcome=Validation criteria=true disease	Sensitivity	Specificity	Combined Sens + Spec
Raitio, Pienihakkinen, et al. 1996 b Poor	181	3 year olds	Longitudinal (11 months)	**Past caries experience-DFS (no white spots included)**; white spot lesions (both WHO criteria)	Plaque; MS (Dentocult-SM); LB (Dentocult-LB); **Candida (Oricult-N)**	Gingivitis; secretion rate; buffering (Dentobuff); **sucrase (Dextrostix)**	Age; gender	Caries increment (no versus some caries)	55% 63% (same variables in caries-free patients)	80% 91%	135 154
Roeters, Verdonschot, et al. 1994 Poor	252	1.9-2.8 year olds	Longitudinal (3 years)	Caries (including **subsurface lesions**; **presence of dentinal lesions;** radiographs taken at end- 5 years old, and interpreted by Marthaler's criteria)	**MS; LB** (both from plaque and saliva); plaque (Suomi-Barbano)	Gingivitis (Silness and Loe)	Diet (24h-recall); use of fluoride	Additional dentinal lesions (ADL) by radiography	60% (by LDA direct method) 51% (by LDA stepwise method) 71% (MS + LB + subsurface enamel lesions) 61%(MS and LB absent and sugar) 25% (sugar and MS) 43% (sugar and brushing frequency) 35% (sugar and hygiene) (Using Discolored enamel only: 43%; and dentinal lesions only: 33%)	94% 92% 79% 73% 56% 47% 42% (Using Discolored enamel only: 84%; and dentinal lesions only: 95%)	154 143 150 134 81 90 77 127 128

Researcher Rating	n	Age at onset	Study Design	Variables: Past Caries or Disease Experience	Variables: Microflora	Variables: Host	Variables: Other	Outcome=Validation criteria=true disease	Sensitivity	Specificity	Combined Sens + Spec
Schroder, Widenheim, et al. 1994 Poor	181	1.5 year olds	Longitudinal (1.5 year olds)	Caries prevalence: manifest and incipient lesions	MS; LB	Not used	**Diet (frequency); oral hygiene** (gingival condition); general health; fluoride use; medication use	Final caries: 0.82 total (manifest + incipient)	12% 42%-67% (adding MS in the second step)	95% 87%-100%	107 ~167
Twetman & Petersson 1996 Fair	1022 (374 low fluoride-0.1 ppm F; 442 fluoride varnish group; 206 optimal fluoride-1.2ppmF)	4-5 year olds	Longitudinal (2 years)	**dfs** (WHO criteria, no radiographs, no incipient lesions)	**MS** (Dentocult)	Not used	**Fluoride exposure**; frequency of snacks; oral hygiene; fluoride habits	Δdfs [Compared to low fluoride group (1.5 ± 2.6), caries incidence was lower, 30% and 60% in F-varnish (1.1 ± 2.0) and optimal fluoride (0.6 ± 1.3) groups, respectively]	Low fluoride: 65% F-varnish: 58% Optimal F: 40%	86% 81% 91%	151 139 131
Twetman, Stahl, et al. 1994 Poor	528	4 year olds	Longitudinal (2 years)	Primary caries experience (WHO criteria; white spots excluded)	MS (Dentocult-SM)	Not used	Not used	Caries increment (dmfs)> 1 (50% remained caries inactive. Caries increment 2.6 for high risk vs. 0.9 for low risk)	67%	75%	142
Cross-sectional studies											
al Ghanim, Adenubi, et al. 1998 Good	446	3-5 year olds	Cross-sectional	dmft (WHO criteria)	Not used	Not used	**Oral hygiene (debris score index); diet**; socio-economic status; medical history; **age of first dental visit**	Caries presence	90.1% (by LRA) 73.4% (by LDA)	80.6% 82.9%	171 156
Ansai, Yamashita, et al. 1994 Fair	260	4-5 year olds	Cross-sectional	dfs (WHO criteria)	MS (Mucount)	Acid potential of plaque (Cariostat)	Not used	Caries prevalence	97%	17%	114

Researcher Rating	n	Age at onset	Study Design	Variables: Past Caries or Disease Experience	Variables: Microflora	Variables: Host	Variables: Other	Outcome=Validation criteria=true disease	Sensitivity	Specificity	Combined Sens + Spec
Cleaton-Jones, Hargreaves, et al. 1991 Fair	395: 189 rural and 206 urban	5 year olds	Cross-sectional	dmfs (WHO criteria, no radiographs)	Not used	CPITN (Community periodontal index of treatment needs)	DI-S (simplified oral debris index); race (black)	dmfs>1	For model 1, rural: 64% Model 1, urban 84% For model 2, rural 93% Model 2, urban 81% Model 3, rural 92% Model 3, urban 77%	22% 43% 24% 46% 26% 55%	86 127 117 127 118 132
Graves et al., 1991 North Carolina Study Fair	4217: 1951 (Aiken, GA) 2266 (Portland, ME) Both: fluoride deficient, high caries experience	6 years (1st grade) and 10 years old (5th grade)	Cross-sectional (Baseline caries prevalence for North Carolina Study)	DMFS, dmfs (Radike. No radiographs), **predicted caries;** fluorosis, **white spot lesions**, caries treatment urgency	SM, LB, mean plaque score	Pit and Fissure Morphology	Sociodemographic (higher in Portland-exclusively white); examiner, age, brushing frequency, between meals snacks; sealants, **number of dental visits in last year, urgency of care of restorative treatment**.	Caries prevalence (dmfs + DMFS)	72% (grade 1); 60% grade 5 72% (grade 1); 62% (grade 5)	90% (grade 1); 86% (grade 5) 91% (grade 1); 86% (grade 5)	162 146 163 148
Schroder and Granath, 1983 Poor	143	3 year olds	Cross-sectional	Caries	Not used	**Gingival status (oral hygiene)**	Dietary habits	Caries prevalence (actual data NR)	89%	70%	159

Continuation TABLE 1. Primary teeth

Researcher Rating	Baseline Scores (Mean ± SD)	True High Risk Criteria Used	Method of modeling	Country	Sampling method	Training of examiners reported	Reliability of examiners	Blinding of examiners	Blinding of patients	Subject Attrition	Authors conclusion
Longitudinal studies											
Demers et al., 1992 Good	NR	At least one new carious lesion in primary teeth: high risk	(LRA; 9 variables studied)	Canada (Montreal) Non-fluoridated community	Random selection of schools	Calibrated (2 examiners)	For caries: Intraexaminer reliability: intraclass correlation coefficient >0.95. The same true for interexaminer reliability For micro test: Intraexaminer reliability:0.80-1.00; interexaminer reliability: 0.79-0.87.	NR	NR	126	Previous caries experience was the best predictor, followed by parent's education.
Holbrook et al., 1993 Poor	NR	High risk: Increment: ≥ 3 new caries lesions in permanent teeth. The total dmfs: ≥ 4	(LRA, stepwise; 14 variables studied)	Iceland (Reykjavik)	Stated that reported previously (previous papers not searched)	NR	NR	NR	NR	NR	Combining tests made the prediction of caries more accurate
Holst & Braune 1994 Poor	No caries by age 1: 67.2%; children with caries: 12.6% ≥4 deft; 7.6% ≥ 8 defs)	For caries risk the patient had to have ≥ 10 points (each variable accounted for different points. Most weight was visible caries-10 points)	All children born in 1987 and living in the area were invited	Sweden (Blekinge)	NR	2 (dental assistants) examiners trained	NR	NR	NR	17	The results suggest this model is cost-effective in pre-school children The criterion for true caries risk was too high.

Researcher Rating	Baseline Scores (Mean ± SD)	True High Risk Criteria Used	Method of modeling	Country	Sampling method	Training of examiners reported	Reliability of examiners	Blinding of examiners	Blinding of patients	Subject Attrition	Authors conclusion
Holst, Martensson, et al. 1997 Fair	NR	Risk if: illness for 1 week more than 4 times/year; use of medications that affect saliva; anything to eat at night; eating more than 6 times at night; oral hygiene less than once/day; no use of fluorides; visible plaque; visible caries	Not used	Sweden (Blekinge)	All children born in 1990 were invited	1 trained dental assistant	NR	NR	Parents informed	20 (82 participated throughout the study)	The model is cost-effective
Isokangas et al., 1993 Good (because reasons for not calibrating and blinding were included)	NR	High risk: Any caries increment	Not used	Finland (Ylivieska)	All 3-16 year olds in public dental care were included	15 clinicians participated No training reported.	NR (dentists examined different children)	Not possible for ethical reasons	NR	NR	Clinicians can predict risk using only caries and sociodemographic variables available at annual examinations
Raitio, Pienihakkinen, et al. 1996 b Poor	NR (these and many other factors were reported previously)	High risk (21%): Presence of past caries and Candida and/or sucrase-positive	LRA	Finland?	NR	NR	NR	NR	NR	NR	The analysis resulted in different models for boys and girls. The combined model for boys and girls was the most clinically sensible model
Roeters, Verdonschot, et al. 1994 Poor	NR	High risk: radiographs revealed dentinal lesions which were not detected by visual inspection (n =27%); no ADL: 73%	LDA (direct-all variables included- and stepwise- only best predictors included-)	The Netherlands (Nijmegen)	NR	2 examiners for radio-graphic diagnosis	NR	NR	NR	70	It is suggested that these risk factors be used in the timing of bitewing radiographs in children The stepwise method provided similar values to the direct method
Schroder, Widenheim et al. 1994 Poor	Low prevalence: 0.02 caries	High risk: Presence of MS and LB	Used also two-step prediction	Sweden (Areas with low fluoride-0.2 ppm F)	All children in the study areas were invited	NR	NR	NR	NR	27 lost	Prediction was not successful with these variables

Researcher Rating	Baseline Scores (Mean ± SD)	True High Risk Criteria Used	Method of modeling	Country	Sampling method	Training of examiners reported	Reliability of examiners	Blinding of examiners	Blinding of patients	Subject Attrition	Authors conclusion
Twetman & Petersson 1996 Fair (although reliability data not included)	Caries at baseline: low fluoride group (1.0 ± 2.2), F-varnish group (1.0 ± 2.4) and optimal fluoride group (0.2 ± 0.9)	dfs > 2 for caries positive; MS ≥ 200 CFU for microbial test positive	Not used	Sweden (Halland)	NR	Reported calibrated examiners used	Assessed	NR	NR	NR	Caries predictive ability decreased with increasing fluoride exposure. Repeated salivary samplings at baseline did not improve predictions. Fluoride exposure should be taken into account when predicting caries.
Twetman, Stahl, et al. 1994 Poor	Low caries prevalence 121 at risk at baseline; 136 low risk at baseline	High risk: SM score ≥ 2 and/or dmfs ≥ 1	Not used	Sweden (Halmstad) Low fluoride in water-0.1 ppm F	NR	NR	NR	NR	Were informed of their caries risk at baseline	15	Strip mutans test as a supplement to clinical examination may be useful in the assessment of caries risk in preschool children.
Cross-sectional studies											
al Ghanim, Adenubi, et al. 1998 Good	No risk: 231 children High risk: 215	Risk if dmft> 8 No risk if dmft=0	LRA (stepwise) LDA	Saudi Arabia (Riyadh)	Random	1 examiner	Interexaminer reliability (kappa for caries 0.96); 98% agreement	NR	NR	NR	Risk factors have been identified in this population LRA and LDA produced model with same variables No socioeconomic variables appeared in the models
Ansai, Yamashita, et al. 1994 Fair	(actual data split up according to combination of results from the 2 tests-table 3)	High risk: 25% of the subjects (dfs ≥ 32)	Not used	Japan (Izumi) non-fluoridated area	NR	1 trained examiner used for both tests; 2 calibrated examiners for caries	Kappa: 0.93 (p<0.01); 98% agreement	NR	NR	NR	MS levels alone are not a good indicator in this age group. Caries activity assessed by both Cariostat and Mucount is useful.

Researcher Rating	Baseline Scores (Mean ± SD)	True High Risk Criteria Used	Method of modeling	Country	Sampling method	Training of examiners reported	Reliability of examiners	Blinding of examiners	Blinding of patients	Subject Attrition	Authors conclusion
Cleaton-Jones, Hargreaves, et al. 1991 Fair	NR	Caries present if dmfs>1 Model 1: DI-S/CPITN: 0.2/0; >0.2/>1 Model 2: <0.2/2; >0.2/>2 Model 3; <0.2/0; >0.2/>3		Namibia and KwaZulu (< 0.15 ppm F)	NR	Calibrated	Kappa for caries greater than 0.80	NR	NR	None	Combination of DI-S and CPITN improved the sensitivity and predictive values in the rural groups and maintained the values for the urban group.
Graves et al., 1991 North Carolina Study Fair	Caries prevalence: Aiken: DMFS: 0.3 dmfs: 4.3 Portland: DMFS: 0.2 dmfs: 2.7	High risk: 25% with highest dmfs+DMFS	(Multiple regression; LDA, 38-43 variables studied)	USA	NR	Reported that examiners were trained and calibrated (4 clinical examiners).	Intraclass correlations exceeded 90%	NR	NR	NR	Lack of consistent association between microbiologic factors and caries was unexpected
Schroder and Granath, 1983 Poor	NR	NR	Not used	Sweden	NR	NR	NR	NR	NR	NR	Children with clean teeth or suitable dietary habits were regarded as no risk for caries; while other combinations of hygiene and diet were caries risks.

TABLE 2. Inclusion Table – Permanent teeth

Researcher Rating	n	Age at onset	Study Design	Variables: Past Caries or Disease Experience	Variables: Microflora	Variables: Host	Variables: Other	Outcome=Validation criteria=true disease	Sensitivity	Specificity	Combined Sens + Spec
Longitudinal studies – Children/adolescents											
Abernathy et al., 1987 Related to North Carolina Study (Preliminary Study) Similar to Stamm et al, 1988 Poor	1253 (Grade 1) and 1384 (Grade 5)	6 years (1st grade), and 10 years (5th grade)	Longitudinal (4 years)	**DMFS**, **defs, Grainger index (eruption pattern by age)**	Not used	Not used	**Socio-economic status;** age, race, sex, fluoridation status	Caries increment (DMFS at 4 years) or DMFS at end of study [Increment: DMFS: Grade 1: 1.0 (high risk), 0.6 (low risk) Grade 5: 7.3 (high risk), 33.5 (low risk) defs; Grade 1:10.7 (high risk), 4.7 (low risk)]	Grade 1, F:46%; Grade1, NF: 49%; Grade 5, F:48%; Grade 5, NF: 57% Grade 1, F: 59%; Grade1, NF: 61%; Grade 5, F: 65%; Grade 5, NF: 71%	Grade 1, F: 82%; Grade1, NF: 83%; Grade 5, F: 82%; Grade 5, NF: 86% Grade 1, F: 85%; Grade1, NF: 88%; Grade 5, F: 88%; Grade 5, NF: 91%	128 132 130 143 144 149 153 162
Alaluusua et al., 1990 Poor	122	12-17 year old	Longitudinal (3 years)	DFS (Moller's criteria-no incipient lesions included; including radiographs)	SM (Dentocult-SM), LB (Dentocult-LB)	Salivary buffer capacity (Dentobuff) flow rate	Not used	Caries increment (3 year-DFS increment: 0.46)	84% (DFS + LB); 71% (DFS + MS)	62% (DFS + LB); 79% (DFS + MS)	146 150
Alanen, Hurskainen, et al. 1994 Fair	7917	5-16 year olds	Longitudinal (1 year)	Caries-DMF (no radiographs); prediction of caries	Not used	Not used	Age; education of clinician	New dentinal caries in permanent teeth needing fillings (Mean: 1.77 at end)	44% (For caries alone: if DMF=0 23%; if DMF>0 50%)	90% (For caries alone: if DMF=0 96%; if DMF>0 80%)	134 119 130
Angulo et al., 1995 Poor	100 (69 included in caries prediction: 34 in Piedras Blancas, and 35 in Pocitos)	12-13 years old	Longitudinal (18 months)	DMFS (criteria for high risk) (WHO criteria; recorded only when cavitation was present)	MS, LB	Not used	Socioeconomic status: Low (Piedras Blancas) High (Pocitos)	ΔDS (Caries incidence; Low risk: 1.2 + 2.1 High risk: 4.2 + 4.0 (p<0.001)	50% (MS + LB) 29% (MS + LB +DS) 92% (>1DS) 14% (MS+LB) 0% (MS+LB+DS) 75% (>1DS)	57% 67% 45% 96% 100% 37%	107 96 137 110 100 112

Researcher Rating	n	Age at onset	Study Design	Variables: Past Caries or Disease Experience	Variables: Microflora	Variables: Host	Variables: Other	Outcome=Validation criteria=true disease	Sensitivity	Specificity	Combined Sens + Spec
Beck et al., 1992 North Carolina Study "Any risk prediction model", "any risk etiologic model (excludes past caries experience variables)" Fair	4117: 2066 (Aiken, GA) 2051 (Portland, ME)	6 years (1st grade) and 10 years old (5th grade)	Longitudinal (3 years)	DMFS (Radike; no radiographs), dmfs, predicted caries; fluorosis, white spot lesions	SM, LB, mean plaque score	Pit and Fissure Morphology	Sociodemographic (higher in Portland-exclusively white); examiner, age, brushing frequency, between meals snacks	Dichotomous: none vs. some caries increment (DMFS) [3-yr DMFS increment: Aiken: 1.9 $\pm$ 2.4 (1st grade); 3.1 $\pm$ 4.3 (5th grade) Portland: 0.8 $\pm$ 1.7 (1st grade); 1.5 $\pm$ 2.7 (5th grade)]	Aiken: Prediction model: 80% (grade 1); 84% grade 5 Etiology model: 74% (grade 1); 81% grade 5 Portland: Prediction model: 66% (grade 1); 76% grade 5 Etiology model: 59% (grade 1); 69% grade 5	Aiken: Prediction model: 61% (grade 1); 54% grade 5 Etiology model: 55% (grade 1); 50% grade 5 Portland: Prediction model: 78% (grade 1); 71% grade 5 Etiology model: 74% (grade 1); 65% grade 5	141 138 129 131 144 147 133 134
Disney et al., 1992 North Carolina Study "High Risk Prediction Model" Good	4158: 2079 (Aiken, GA) 2079 (Portland, ME) Both: fluoride deficient, high caries experience	6 years (1st grade) and 10 years old (5th grade)	Longitudinal (3 years)	**DMFS (Radike, no radiographs),** dmfs, **predicted caries;** fluorosis, white spot lesions	SM (Cariescreen), LB (Bactotest), mean plaque score	**Pit and Fissure Morphology**	Socio-demographic (higher in Portland-exclusively white); examiner, age, brushing frequency, between meals snacks	$\geq$4 DMFS $\geq$ 2 DMFS (At 3 years-DMFS increment: Aiken: 1.9 (grade 1), 3.1 (grade 5) Portland: 0.8 (grade 1), 1.5 (grade 5)	59% (grade 1); 62% grade 5 59% (grade 1); 62% (grade 5)	83% (grade 1); 81% (grade 5) 84% (grade 1); 84% (grade 5)	142 143 143 146
Isokangas et al., 1993 Good	1464 (5-16 year olds)	5-16	Longitudinal (1 year)	Caries, **Predicted caries**	Not used	Not used	Socio-demographic	$\leq$1 dentinal caries lesion in need of restoration (Actual data NR)	5-16 year olds: 58%	5-16 year olds: 84%	142

Researcher Rating	n	Age at onset	Study Design	Variables: Past Caries or Disease Experience	Variables: Microflora	Variables: Host	Variables: Other	Outcome=Validation criteria=true disease	Sensitivity	Specificity	Combined Sens + Spec
Leverett et al., 1993b Poor	472 (286 from fluoridated community (New York); 186 from non-fluoridated (<0.3 ppm F) community (New York)	6 years	Longitudinal (1.5 years)	DMFS (Radike); **Fluorosis** (Dean)	Plaque (Loe); **SM, LB**	**Salivary phosphate**, calcium and fluoride	Demographic data; fluoride exposure; dietary habits; oral hygiene	$\geq$1 DS (Actual data not reported)	82.8%	82.4%	165
Mattiasson-Robertson & Twetman 1993 Poor	655 (333-low fluoride-0.1 ppm F; 322 optimal fluoride-1.2 ppm F)	12 year olds	Longitudinal (3 years)	**DMFS (Koch criteria);** approximal caries (radiographs used)	MS (Dentocult)	Not used	Fluoride exposure	ΔDMFS [Caries increment similar in both fluoride groups (1.2 low F; 1.4 optimal F); significantly more approximal lesions increment in high fluoride group (4.0 vs. 3.1)]	Low fluoride: 87% Optimal F: 73% For previous caries experience only: Low F: 60% Optimal F: 32%	36% 48% 78% 91%	123 121 138 123
Pienihakkinen, 1987 Poor	284 (139 xylitol group, 145 fluoride/control-FC groups combined. Part of a WHO xylitol study)	7-12 years old (Hungary)	Longitudinal 2 years	DMFS (no incipient lesions) **Incipient caries on buccal/lingual tooth surface** (not measured at occlusal sites)	**LB (Dentocult)-high $\geq 10^5$ CFU/ml; yeasts (Oricult)-high $>10^3$ CFU/ml**	Salivary buffer capacity (Dentobuff): Low $\leq$ 5.0	Age	Caries increment (ΔDMFS) (Actual data NR)	70% (xylitol group) 63% (FC group) 52% (previous caries experience only in xylitol group)	71% (xylitol group) 69% (FC group) 87%	141 132 139

Researcher Rating	n	Age at onset	Study Design	Variables: Past Caries or Disease Experience	Variables: Microflora	Variables: Host	Variables: Other	Outcome=Validation criteria=true disease	Sensitivity	Specificity	Combined Sens + Spec
Steiner et al., 1992 Note: Included data only on 3-input model Poor	3419 Age 7/8: 1708 (For each period: 586, 583, 334, 205) Age 10/11: 1713 (For each period: 372, 650, 433 and 258, respectively)	7/8 year olds and 10/11 year olds	Longitudinal (4 years; in 4 periods: 1972-1976; 1976-1980; 1980-1984; 1984-1988)	DFS and dfs on right side only (only cavitated lesions, including or not radiographs). The following were good predictors: For both age groups: **Sound primary molars**; sound primary teeth; sound approximal surface in primary molars; D1 (enamel) in first molar approximal surfaces. For 7/8 year olds: df; df approximal. For 10/11 year olds: **White spots on smooth surfaces of first permanent molars;** D1 (enamel) in permanent premolars.	Not used	Not used	**Dark, discolored pit and fissures in primary 1st molar**	C2 (2 or more DF sites) C3 (3 or more) C4 (4 or more) (Actual data NR)	1972 data set: For 7/8 : 56% (C4); 74% (C3); 62% (C2) For 10/11: 56% (C4); 55% (C3); 62% (C2) 1976 data set: For 7/8 : 68% (C4); 66% (C3); 67% (C2) For 10/11: 69% (C4); 66% (C3); 59% (C2) 1980 data set: For 7/8: 72% (C4); 69% (C3); 71% (C2) For 10/11: 65% (C4); 73% (C3); 71% (C2) 1984 data set: For 7/8: 75% (C4); 82% (C3); 62% (C2) For 10/11: 76% (C4); 75% (C3); 71% (C2)	For 7/8 : 70% (C4); 53% (C3); 60% (C2) For 10/11: 63% (C4); 66% (C3); 56% (C2) For 7/8 : 71% (C4); 66% (C3); 64% (C2) For 10/11: 64% (C4); 62% (C3); 66% (C2) For 7/8: 83% (C4); 71% (C3); 65% (C2) For 10/11: 71% (C4); 63% (C3); 63% (C2) For 7/8: 91% (C4); 88% (C3); 87% (C2) For 10/11: 65% (C4); 72% (C3); 73% (C2)	126 127 122 119 121 118 139 132 131 133 128 125 155 140 136 136 136 134 166 170 149 141 147 144

Researcher Rating	n	Age at onset	Study Design	Variables: Past Caries or Disease Experience	Variables: Microflora	Variables: Host	Variables: Other	Outcome=Validation criteria=true disease	Sensitivity	Specificity	Combined Sens + Spec
Stewart and Stamm, 1991 Related to North Carolina Study Includes data of CART vs. LRA and LDA (Not in table) Poor	1938: 914 (Aiken, South Carolina) and 1024 (Portland, Maine)	6years;1st grade	Longitudinal (2 years)	**dmfs (posterior teeth only- 3, 4 and 5);** DMFS	MS, LB	Morphology	Age, sex, race, brushing frequency, use of fluoride products, antibiotic use	≥2 DMFS	Aiken; 64% Portland: 62%	Aiken: 86% Portland: 77%	150 139
Wilson & Ashley 1989 Fair	101	11-12 year olds	Longitudinal (2,3 years)	Baseline caries experience (no radiographs; no incipient lesions-DFS)	**MS**; LB (Dentocult assays)	**Buffering (Dentobuff)**	Sugar intake and frequency	2 year-DMF increment (For low risk: 1.30; for high risk: 8.81) 3 year-DMF increment (For low risk: 2.59; for high risk: 14.53)	63%	78%	141
Retrospective studies– Children/adolescents											
Tuomi, 1989 Poor	516	8, 13 year olds	Retrospective (3 years for 8 year olds and 5 years for 13 year olds)	dmf /DMF	Not used	Not used	Obesity by age 3-6 (for 8 year olds) and age 7-12 (for age 13) Sex	True risk if: DMF>0 (Actual data NR)	For 8yo girls: 67%; For 8 year old boys:72%; For 13 year old girls 94%; For 13 year old boys: 87% Considering previous caries experience only: For 8 year old girls:56%; for 8 year old boys: 61%; for 13 year old girls: 88%; for 13 year old boys: 79%	For 8 year old girls:72%; For 8 year old boys:75%; For 13 year old girls 79% For 13 year old boys: 63% For 8 year old girls:75%; for 8 year old boys:78%; for 13 year old girls: 79%; for 13 year old boys: 65%	139 147 173 150 131 139 167 144

Researcher Rating	n	Age at onset	Study Design	Variables: Past Caries or Disease Experience	Variables: Microflora	Variables: Host	Variables: Other	Outcome=Validation criteria=true disease	Sensitivity	Specificity	Combined Sens + Spec
Vehkalahti, Nikula-Sarakorpi, et al. 1996 Poor	66	15 year olds	Retrospective (28 months)	DMFS (WHO criteria; no incipient lesions)	MS (Dentocult-SM), LB (Dentocult-LB) (alone or combined amongst them)	**Flow rate; buffer capacity** (Dentobuff) (Alone or combined amongst them)	Not used	ΔDFS>0 (reaching dentine; on selected surfaces) (Mean ΔDFS was 1.1-70% on occlusal surfaces; final DMF 6.7 ± 3.5)	53% (combination of flow rate + buffer) For DMFT alone (>3): 87%, (>7) 33%	82% (>3) 44%; (>7) 81%	135 131 114
Cross-sectional studies– Children/adolescents											
Graves et al., 1991 North Carolina Study Fair	4217: 1951 (Aiken, GA) 2266 (Portland, ME) Both: fluoride deficient, high caries experience	6 years (1st grade) and 10 years old (5th grade)	Cross-sectional (Baseline caries prevalence for North Carolina Study)	DMFS, dmfs (Radike. No radiographs), **predicted caries;** fluorosis, **white spot lesions**, caries treatment urgency	SM, LB, mean plaque score	Pit and Fissure Morphology	Sociodemographic (higher in Portland-exclusively white); examiner, age, brushing frequency, between meals snacks; sealants, **number of dental visits in last year, urgency of care of restorative treatment**.	Caries prevalence	72% (grade 1); 60% grade 5 72% (grade 1); 62% (grade 5)	90% (grade 1); 86% (grade 5) 91% (grade 1); 86% (grade 5)	162 146 163 148
Leverett et al., 1993a Poor	313 (140 from fluoridated community (New York); 173 from non-fluoridated (<0.3 ppm F) community (New Hampshire)	12-15 years old	Cross-sectional	DMFS (Radike; no radiographs); fluorosis (Dean's)	**Plaque (Loe's plaque Index), MS, LB**	**Saliva fluoride concentration**	Demographic data; fluoride exposure (**F supplement; age began using F dentifrice);** dietary habits **(length bottle-fed);** oral hygiene	Zero-DMFS High-DMFS (High caries: 39.3% from fluoridated community, 41% from non-fluoridated community)	For fluoridated community: 79.3%; for non fluoridated community: 88.1%	For fluoridated community: 77.6%; for non-fluoridated community: 86.1%	157 174

Researcher Rating	n	Age at onset	Study Design	Variables: Past Caries or Disease Experience	Variables: Microflora	Variables: Host	Variables: Other	Outcome=Validation criteria=true disease	Sensitivity	Specificity	Combined Sens + Spec
Normark, 1993 Good	610	7.15 year olds	Cross-sectional	Caries at the surface level only: DMF (criteria of the National Health Survey of Uganda); caries in dentin specified as D2 according to WHO	Plaque score (Loe)	Not used	Demographic (**area, tribe,** religion); socioeconomic status (**education, literacy**, home's building material, **clothing**); oral health related habits (**tooth-cleaning** frequency, F in toothpaste, daily meals, frequency of carbohydrate)	% with >10 DMFS+dmfs (8% for 7-yr old; 12% for 15-yr olds with ≥ 12 DMFS)	Rural-7 year olds: 86% Rural-15 year olds: 70%	81% 79%	167 149
Longitudinal studies– Adults											
Hawkins et al., 1997 Good	493	50+	Longitudinal 3 years	No calculus removed no radiographs Third molars excluded Mean AL (baseline) No of teeth (baseline) Coronal DF	Not Used	Not Used	**Educational level;** **Marital status;** Age; Total; household income; Dental visiting pattern; Born in Canada; Major life event in past 6 months; Wearing partial denture	One or more net coronal DFS increments	80.2	46.2	126

Researcher Rating	n	Age at onset	Study Design	Variables: Past Caries or Disease Experience	Variables: Microflora	Variables: Host	Variables: Other	Outcome=Validation criteria=true disease	Sensitivity	Specificity	Combined Sens + Spec
MacEntee et al., 1993 Poor	156	65+	Longitudinal 1 year	No radiographs teeth not dried Caries at baseline (1,2)	**PI** (1,2,**3**) MS count baseline (1,2,3) **LB** count baseline (1,2,**3**)	Stimulated salivary flow rate	**Residence** (**1**,2); Medications (1,2,3); Xerostomic medications (1,2,3;) Age; Sugar consumption; Oral hygiene	DS	Model 1: 63 Model 2: 70: Model 3: 72	Model 1: 79 Model 2: 77 Model 3: 58	142 147 130
Cross-sectional studies– Adults											
Sakki et al., 1994 Good	533	55	Cross sectional	Radiographs used WHO criteria for caries	Not Used	Not Used	**Frequency of dental visits; Frequency of tooth brushing; Combined lifestyle variable (included Dietary, smoking, physical activity, Alcohol consumption**); Consumption of sweets; Attitude to preservation of natural teeth	DS (3 or more versus 0-2)	61.4	76.5	138

Researcher Rating	n	Age at onset	Study Design	Variables: Past Caries or Disease Experience	Variables: Microflora	Variables: Host	Variables: Other	Outcome=Validation criteria=true disease	Sensitivity	Specificity	Combined Sens + Spec
Sayegh et al., 1997 Fair	180	Final year university students	Cross sectional	DMFS clinical and radiographic	MS LB Plaque accumulation	Salivary flow rate Buffering capacity	Oral hygiene; Between meal sugar intakes; sex	DMFS mean DMFS 75th percentile	DMFS mean: 64.7 (discriminant) 75.0 (logistic) DMFS 75th percentile 70.5 (discriminant) 79.5 (logistic)	DMFS mean: 82.1 (discriminant) 70.5 (logistic) DMFS 75th percentile 91.9 (discriminant) 75.0 (logistic)	147 146 162 155

Continuation TABLE 2. Permanent teeth

Researcher Rating	Baseline Scores (Mean ± SD)	True High Risk Criteria Used	Method of modeling	Country	Sampling method	Training of examiners reported	Reliability of examiners	Blinding of examiners	Blinding of patients	Subject Attrition	Authors conclusion
Longitudinal studies – Children/adolescents											
Abernathy et al., 1987 Related to North Carolina Study (Preliminary Study) Similar to Stamm et al, 1988 Poor	NR	Highest 25% of children based on DMFS increment or total DMFS at end.	(LDA; using 13 variables)	USA	NR	NR	NR	NR	NR	NR	The prediction model is more effective when using final DMFS as the discriminating factor
Alaluusua et al., 1990 Poor	DFS: 6.7 ± 6.3	Risk group: 25 % of the subjects (DFS>3; MS+LB≥ 5)	Not used	Finland (Helsinki)	NR	NR	NR	NR	NR	24 children	A combination of DFS and microbial test was more effective than various alternatives alone.

Researcher Rating	Baseline Scores (Mean ± SD)	True High Risk Criteria Used	Method of modeling	Country	Sampling method	Training of examiners reported	Reliability of examiners	Blinding of examiners	Blinding of patients	Subject Attrition	Authors conclusion
Alanen, Hurskainen, et al. 1994 Fair	Baseline DMF: 1.3	At risk if at least 1 new dentinal lesion to be filled	Not used	Finland	NR	77 examiners used: 52 dentists and 25 hygienists Not trained	NR	Yes	NR	NR	Dentists were better predictors than hygienists. The prediction increased if the dentist knew the child On average clinicians did not reach high predictive values
Angulo et al., 1995 Poor	NR	DS>3; MS $>10^4$, LB> 10^4 or DS>10; MS $>10^4$,LB> 10^3	Not used	Uruguay (Montevideo)	NR	NR	NR	NR	NR	19 from original low risk group	The highest sensitivity was obtained with the clinical test, and the higher specificity with clinical + microbiological (regardless of socioeconomic background)
Beck et al., 1992 North Carolina Study "Any risk prediction model", "any risk etiologic model (excludes past caries experience variables)" Fair	NR	Any caries increment	(LRA, stepwise, 39-44 variables studied)	USA	NR	Training reported	Examiner reliability; intraclass correlations above 90% for 10/12 comparisons. Reliability for noncaries data showed fair agreement among examiners.	NR	NR	4% at baseline (N+4%) ; at end betwee n 19-22% were lost	The "any risk models" have the highest sensitivity; while the "high risk prediction models" have the highest specificity.
Disney et al., 1992 North Carolina Study "High Risk Prediction Model" Good	Aiken: DMFS:0.3 (grade 1), 3.0 (grade 5) dmfs: 9.3 (grade 1), 4.4 (grade 5) Portland; DMFS:0.2 (grade 1), 1.7 (grade 5) dmfs: 2.9 (grade 1), 2.4 (grade 5)	High risk:25% of the total sample size.	(LRA, stepwise, 38-43 variables studied)	USA	NR	Trained	Examiner reliability; intraclass correlations above 90% for 10/12 comparisons. Reliability for noncaries data showed fair agreement among examiners.	Yes	NR	Lost approx. 20% from baseline (more than N)	Models had high specificity for children at low risk. Clinical predictors were the most important ones, while the other factors contributed little to the prediction.

Researcher Rating	Baseline Scores (Mean ± SD)	True High Risk Criteria Used	Method of modeling	Country	Sampling method	Training of examiners reported	Reliability of examiners	Blinding of examiners	Blinding of patients	Subject Attrition	Authors conclusion
Isokangas et al., 1993 Good (because reasons for not calibrating and blinding were included)	NR	High risk: Any caries increment	Not used	Finland (Ylivieska)	All 3-16 year olds in public dental care were included	15 clinicians participated. No training reported.	NR (dentists examined different children)	Not possible for ethical reasons	NR	NR	Clinicians can predict risk using only caries and sociodemographic variables available at annual examinations
Leverett et al., 1993b Poor	NR	Caries group: If developed any caries at their 3rd or 4th examination.	(LDA; 8 variables studied)	USA (New York)	NR	NR	NR	NR	NR	13% of N lost	Results are encouraging for individual patient risk assessment
Mattiasson-Robertson & Twetman 1993 Poor	Caries prevalence at baseline; Low fluoride: DMFS: 2.2 ± 2.5; approximal 2.1 ± 2.3 Optimal fluoride: DMFS: 1.5 ± 2.0; approximal: 1.0 ± 1.8 ($p<0.001$)	Positive test: MS score >1; >4 DMFS or approximal enamel lesions at baseline Disease: > 3 new lesions	Not used	Sweden (Halmstad and Kungsbacka)	NR	NR	NR	Yes	NR	Originally 698	Natural fluoride has a limited influence on caries prediction in a population with low level of disease
Pienihakkinen, 1987 Poor	NR	Caries active in xylitol group: ΔDMFS=2 In FC groups: ΔDMFS=5	(LRA)	Hungary	NR	NR	NR	NR	NR	NR	The results suggest that the 2 strongest variables in combination have good ability to distinguish high and low caries increment (The use of xylitol did not weaken the prediction)

Researcher Rating	Baseline Scores (Mean ± SD)	True High Risk Criteria Used	Method of modeling	Country	Sampling method	Training of examiners reported	Reliability of examiners	Blinding of examiners	Blinding of patients	Subject Attrition	Authors conclusion
Steiner et al., 1992 Poor	DMFT at age 12: 1972-76= 5.30 1976-80= 3.90 1980-84= 3.22 1984-88= 2.39	Criteria for variable entering the models: p= 0.025, and exit p= 0.03	LRA (46 variables tested), stepwise (22 variables tested) 3 variables reported in model included in this table	Switzerland (Zurich)	NR	NR	NR	NR	NR	NR	Inclusion or not of radiological data did not improve the prediction. Prediction is better in low risk group
Stewart and Stamm, 1991 Related to North Carolina Study Poor	NR	High rate if DMFS increment ≥ 2	(CART 38-43 variables studied)	USA	NR	NR	NR	NR	NR	NR	Very poor sensitivities if models from one city were applied to the other city CART performed as well as LDA and LRA More work on CART needed
Wilson & Ashley 1989 Fair	NR	High risk: 25% of subjects; 2year-DMF increment ≥ 5; 3 year-DMF increment ≥ 8	LDA	United Kingdom (London)	NR	The examiner was experienced	The examiner had proven reproducibility	NR	NR	17 – by 2 years; and 18 - by 3 years	The results indicate that salivary diagnostic tests have a potential, but need further development before they can be used All variables had a weak association with caries, except for previous caries experience (best individual predictor), which was “other than weak”
Retrospective Studies – Children/adolescents											

Researcher Rating	Baseline Scores (Mean ± SD)	True High Risk Criteria Used	Method of modeling	Country	Sampling method	Training of examiners reported	Reliability of examiners	Blinding of examiners	Blinding of patients	Subject Attrition	Authors conclusion
Tuomi, 1989 Poor	6.9-16.8% obese; 8yr olds included in risk at baseline if dmfs>4 at 5 years of age; 13 yr-olds included in risk at baseline if DMF > 2 (permanent first molars) at age 8.	True risk if DMF > 0	Not used	Finland (Luvia)	NR	NR	NR	NR	NR	Not applica ble	The combination of variables offer good prediction for 1st permanent molar, and even better for 2nd permanent molar, and as good a prediction as other methods using other lab tests Obesity did not add to the prediction in all cases
Vehkalahti, Nikula-Sarakorpi, et al. 1996 Poor	DMFT: 5.7 ± 3.1	High risk: <0.2 ml/min unstimulated flow rate; < 1.0 ml/min stimulated flow rate; buffering: final pH below 4.5; SM ≥ 10^5 CFU/ml; LB ≥ 10^5 CFU/ml	Not used	Finland (Helsinki)	NR	Clinical parameters by 4 experienced calibrated teachers; Microbial tests by 1 experienced instructor	NR	NR	NR	NR	The strongest salivary indicator of caries increment were high LB (alone, and a high combination of LB+MS, and a low score for the combination of flow+buffering.
Cross-sectional studies – Children/adolescents											
Graves et al., 1991 North Carolina Study Fair	Caries prevalence: Aiken: DMFS: 0.3 dmfs: 4.3 Portland: DMFS: 0.2 Dmfs: 2.4	High risk: 25% with highest dmfs+DMFS	(Multiple regression; LDA, 38-43 variables studied)	USA	NR	Reported that examiners were trained and calibrated (4 clinical examiners).	Intraclass correlations exceeded 90%	NR	NR	NR	Lack of consistent association between microbiologic factors and caries was unexpected
Leverett et al., 1993a Poor	DMFS: 12.09 ± 4.75 (non-fluoridated); 13.38 ± 7.78 (fluoridated)	High Caries (approx. 20% of samples): active lesion and DMFS ≥ 6 (in fluoridated community), DMFS ≥ 8 in non-fluoridated community	(LDA; 7 key variables)	USA	NR	NR	NR	NR	NR	NR	DMFS best predictor (stated at beginning of discussion). Plaque analysis was difficult and did not add to the prediction.

Researcher Rating	Baseline Scores (Mean ± SD)	True High Risk Criteria Used	Method of modeling	Country	Sampling method	Training of examiners reported	Reliability of examiners	Blinding of examiners	Blinding of patients	Subject Attrition	Authors conclusion
Normark, 1993 Good	For 7year olds: DMFS +dmfs: 4.1 (urban), 1.8 (rural) For 15 years old; DMFS: 5.3 (urban) and 3.5 (rural):	Area, tribe, clothing affect caries of children living in urban areas.	(Multivariate analysis: Logistic regression)	Sierra Leon	Randomly selected after stratification for area and predominant religion.	NR (but most have been done because of the reliability data?)	Intraexaminer reproducibility: 82%; interexaminer reproducibility: 70%; inter-interviewer reliability: 67-100%	NR	NR	NR	Social criteria were sufficient to classify rural children with high caries experience, but not urban children.
Longitudinal studies – Adults											
Hawkins et al., 1997 Good	Caries incidence 57% Mean net increment 1.91±2.60	NR	LRA	Canada, Ontario	Random	Calibration reported	94% kappa 0.76 coefficient of reproducibility 0.97 ($p<0.001$)	NR	NR	206 (from initial 699 recruited)	Non-clinical factors, which showed significant effects were education and marital status, both of these factors may influence attitudes towards oral health. The baseline no. of teeth and mean periodontal AL may measure the number of tooth surfaces at risk of decay.
MacEntee et al., 1993 Poor	Mean DS 5.2±10.2; Mean DFS 37.9±27.0; PI 1.1±0.8; Meds/day 2.7±2.2	NR	SRA	Canada	NR	Training reported	NR	NR	NR	49 (lost from original 205)	Caries risk in old age increases noticeably when there are high numbers of LB, frequent sugar intake and poor oral hygiene.
Cross-sectional studies – Adults											
Sakki et al., 1994 Good	Mean DS 2.5 ± 6.6. But 247 edentulous persons also included	3 or more DS	SLRA	Finland	All 55 yr old inhabitants of a town 78% agreed to participate, 53 % were dentate.	Calibration 2 examiners	Agreement 99.1% kappa 0.77	NR	NR	NR	The association of lifestyle with dental caries supports the idea that behavior in a broader sense should be taken into consideration in caries prevention

Researcher Rating	Baseline Scores (Mean ± SD)	True High Risk Criteria Used	Method of modeling	Country	Sampling method	Training of examiners reported	Reliability of examiners	Blinding of examiners	Blinding of patients	Subject Attrition	Authors conclusion
Sayegh et al., 1997 Fair	Mean values: Salivary flow rate: 1.41±0.71 Buffering capacity 5.21±0.84 Log. No of MS 5.8±1.4 Log no. of LB 1.9±1.0 DMFS clinical and radiographic 8.17±7.5	DMFS mean DMFS 75th percentile	Discriminant and logistic analyses SLRA	Jordan	Random	One examiner trained	NR	NR	NR	NR	Logistic results here are far from being accurate since there are still high chances of misclassification. Students at high risk were those with a high LB count, a high plaque index, whose in-between meal snacks were sugar containing. Further more females were more at risk than males

TABLE 3. Inclusion - Root Surfaces

Researcher Rating	n (dentate)	Age at outset	Study Design	Variables: Past Caries or Disease Experience	Variables: Microflora	Variables: Host	Variables: Other	Outcome=Validation criteria=true disease	Sensitivity %	Specificity %	Combined Sens + Specif
Longitudinal Studies											
Joshi et al., 1993 Poor	130 middle-aged and older adults	45-70+	Longitudinal (9-24 months)	No radiographs Third molars excluded **Baseline DFS** (root)	**Mean plaque score**	**Teeth status** (more or less than 22 teeth); Oral hygiene maintenance Poor/ adequate	Follow up time in months	Annualized Root DFS increment	69.7	64.1	134

Researcher Rating	n (dentate)	Age at outset	Study Design	Variables: Past Caries or Disease Experience	Variables: Microflora	Variables: Host	Variables: Other	Outcome=Validation criteria=true disease	Sensitivity %	Specificity %	Combined Sens + Specif
Locker, 1996 Fair	699	50+	Longitudinal 3 years	Third molars excluded Baseline root DFS Mean AL Mean DS (crown)	Not Used	Not Used	**Age** **Age** **Dental visiting pattern; Partial denture wearing;** Smoking history; Self-rated general health; Brushing frequency; Living rurally; Dental insurance	DFS (root) DS (root)	6.7, 9.2 (when baseline root DFS included) 1.5 7.5 including baseline root DFS	NR	Cannot be calculated
Powell et al., 1991 Poor	23	65+ semi-independent retirement center	Longitudinal 1 year	Only facial surfaces of roots were evaluated DFS% **RCI**	Cultured whole stimulated saliva MS on Mitis salivarius @ 37˚ and 95%N –5% CO for 2 days LM on Rogosa agar @ 37˚ for 4 days	Flow rate of stimulated saliva; Buffer capacity (Dentobuff®) OHI-C	Age **Gender**	≥1 vs. ≤1 new root caries ≥2 vs. ≤2 new root caries ≥3 vs. ≤3 new root caries (Actual versus predicted outcome)	69 100 75	75 88 94	144 188 169
Scheinin et al., 1992 Poor	104	47-79	Longitudinal 1 year	Coronal and root caries according to WHO criteria Radiographs used DFS; **RDFS; RD1**	MS (Dentocult) **LB** (Dentocult-LB) **Candida**/Yeasts (Oricult-N)	Sucrase activity (Dextrostix); Salivary secretion rate (ml/min); Salivary buffer effect (pH)	**VPT%** Chronic medication Age; Gender	Root caries increment	78.6	87.9	167
Scheinin et al., 1994 Same study as previous, but run 2 years longer Poor	104	47-79	Longitudinal 3 years	Coronal and root caries according to WHO criteria Radiographs used DFS; RDFS; RD1	MS (Dentocult) **LB** (Dentocult-LB); **Candida**/Yeasts (Oricult-N)	Sucrase activity (Dextrostix) Salivary secretion rate (ml/min) Salivary buffer effect (pH)	VPT% ; Chronic medication Age; Gender	(1,2,3) year root caries increment cut off "2 or 3 positive tests of RFDS, LB, Candida"	3yr 77.6 2yr 81.8 1yr 85.7	3yr 76.6 2yr 67.7 1yr 74.1	154 150 160
Cross-sectional Studies											

Researcher Rating	n (dentate)	Age at outset	Study Design	Variables: Past Caries or Disease Experience	Variables: Microflora	Variables: Host	Variables: Other	Outcome=Validation criteria=true disease	Sensitivity %	Specificity %	Combined Sens + Specif
Steele et al., 1997 5 models Poor	1228 dentate adults	60 and over	Cross-sectional	One edentulous arch (1, 2, 3, 4, 5) crowns (1); **Wearing RPD** (1,3,4); teeth with vulnerable but sound root surfaces (1, 2, 3, 4); **Teeth with sound root surface fillings** (3, 5); Teeth with sound coronal surfaces (2,4); Teeth with sound coronal fillings (3,4); **Teeth with unsound coronal fillings** (3,5); Teeth with untreated new coronal decay (2,3,4); Teeth with gross coronal decay (3); Missing teeth (3,4,5)	Not Used	**Being male** (1)/ **Regular use of any medication** (2) **Use of sugar in tea/coffee** (5)	Reported irregular dental attendance (2); Coming from **north of England** (2); living in north of England (4); **being retired** (3,4,5); Living in a rural area (4); **Partial denture by infrequent brushing** (4)	1:Presence of teeth with decayed or filled root surfaces 2: Presence of any teeth with root surface fillings 3: Presence of any teeth with unsound roots (new decay or failing restorations). 4: Presence of any teeth with new untreated decay of the root surfaces 5: Presence of any teeth with unsound restorations on the root surfaces	1: 91 2: 79 3: 51 4: 40 5: 19	1: 40 2: 67 3: 82 4: 90 5: 99	131 146 133 130 118

Continuation TABLE 3. Root Surfaces

Researcher Rating	Baseline Scores (Mean ± SD)	True High Risk Criteria Used	Method of modeling	Country	Sampling method	Training of examiners reported	Reliability of examiners	Blinding of examiners	Blinding of patients	Subject Attrition	Authors conclusion
Longitudinal Studies											
Joshi et al. 1993 Root caries incidence and associated risk factors in middle-aged and older adults Poor	Baseline DFrootS: (45-59)=3.7±3.7 (60-64)=4.0±4.8 (65-69)=4.4±4.2 (70+)=6.5±7.5	Presence or absence of new root caries	LRA	USA	NR	One examiner Training and calibration reported	NR	NR	NR	NR	Past root caries experience, high plaque score, and high number of teeth (≥ 22) were found to be positively associated with new root caries ($p < 0.05$)
Locker, 1996 Fair (because no specificity was reported, which was an inclusion criteria)	% with 1 or more DFS increments (50-64) 25.1% (65-74) 26.4% (75+) 47.8%		Multiple and LRA	Ontario, Canada	Random	Calibrated dental hygienists	% Agreement (coronal): 96.4% κ=0.91 (root) 97.5%κ=0.60	NR	NR	206	In LRA, age was the only variable associated with one or more root DFS increments, while age, dental visiting pattern and wearing a partial denture were associated with one or more root DS increments. In both cases, the predictive power of the models was poor but improved marginally when baseline root caries experience was entered as an independent variable
Powell et al., 1991 Poor	NR	NR	LRA	USA, Seattle	NR	One examiner	NR	NR	NR	2	The proposed method has the advantages of easily collected data, individualized criteria, and the ability to order patients as to the relative risk of developing decay
Scheinin et al., 1992 Poor	NR	NR	Multifactorial modeling	Finland, Turku	NR	NR	NR	NR	NR	4	Estimates of past root caries experience and plaque, tests for candida and LB can be used to identify the majority of subjects with and with out root caries risk
Scheinin et al., 1994 Poor	NR		LRA	Finland, Turku	NR	NR	NR	NR	NR	8	The best model included RFDS, LB, VPT, and salivary buffer effect. However, this model was only marginally better than the described 3 variable models and did not result in logical grouping at the selection of screening criterion.

Researcher Rating	Baseline Scores (Mean ± SD)	True High Risk Criteria Used	Method of modeling	Country	Sampling method	Training of examiners reported	Reliability of examiners	Blinding of examiners	Blinding of patients	Subject Attrition	Authors conclusion
Cross-sectional Studies											
Steele et al. 1997 Partial dentures as independent indicator of root caries risk 5 models Poor	NR	NR	LRA	England	NR	4 examiners Training & calibration reported	NR	NR	NR	NR	In this study, where RPDs were present, the odds of untreated disease being present increased substantially

Abbreviations used in all tables:
* **Bold**: included in final models or strongest predictors
AA: Actinobacillus actinomycetemcomitans
AL: Attachment loss
BF: Bacteriodes forsythus
GR: Gingival recession
LB: Lactobacilli
LDA: Logistic discriminant analysis
LRA: Logistic regression analysis
MCA: Multiple classification analysis
MRA: Multiple regression analysis
MS: Mutans streptococci
NR: Not reported
NSAOHUS: National Survey of Adult Oral Health in the United States
OHI-C Oral hygiene index for calculus
OLR: Ordinal logistic regression
PG: Porphyromonas gingivalis
PI: Plaque index of Silness and Loë
PI: Prevotella intermedius
PPD: Probing pocket depth
PS%: Percentage of tooth surfaces harboring plaque
RCI: Root caries index
RD1: Incipient demineralization of exposed root surfaces
RPD: Removable partial denture
RPD: Removable partial denture

SLRA: Stepwise logistic regression analysis
SMRA: Stepwise multiple regression analysis
SRA: Stepwise regression analysis
SS: S. sobrinus, CFUx10^5 /ml
TD: Treponema denticola
VPT%: Visible plaque teeth

TABLE 4: EXCLUSION TABLE

Researcher	Age	Reason for exclusion
Alaluusua 1993	12-17 year olds	Several variables analyzed separately
Alaluusua and Malmivirta, 1994	19 month olds	Variables analyzed separately
Angelillo, Anfosso, et al. 1998	6,12,15 year olds	No sensitivity or specificity reported
Astrom, Awadia, et al. 1999	15-40 year olds	Survey of risk perception. No prediction outcome-caries measured.
Axelsson et al., 1998	35-75	Dental status of smokers/ non smokers: no prediction
Banting, 1993		Review
Becart, Hedouin, et al. 1997	16-35 year olds	Only 1 factor (heroin use) related to caries prevalence
Beck et al., 1988		Review
Beck and Drake, 1997	65+	Multiple variables used but Sensitivity and specificity not reported
Beighton et al., 1989	15, 19 years old	Correlation between SM,LB and caries prevalence
Bergendal & Hamp 1985	19 year olds	Correlation data reported. No sensitivity and specificity reported
Berset et al., 1996	35+	Multiple variables used but Sensitivity and specificity not reported
Billings, 1993	20-80+	Association between Root caries prevalence and hyposalivation
Bjarnason & Grondahl 1996	12; 15-16; 18-19 year olds	Assessed only location of caries as a risk factor (cross-sectional study)
Bjarnason & Kohler 1997	15-16 year olds	Multiple variables analyzed separately. Analyzed together white spots + cavitated lesions (past caries experience variables) as predictors.
Bjarnason, Kohler, et al. 1993	15 year olds	Correlation of bacteria with caries.
Bjertness, 1991	35	Multiple variables used but Sensitivity and specificity not reported
Bjertness and Eriksen, 1992	50	Multiple variables used but Sensitivity and specificity not reported
Bokhout, Van Loveren, et al. 1996	18 months old	No caries data nor outcome (article deals with risk of infection)
Brodeur, Payette, et al. 1998	2^{nd} and 6^{th} graders	Not in English
Clarke, Locker, et al. 1996	14+ year olds	No sensitivities or specificities reported (not a prediction paper)
de Liefde, 1989	5-8 year olds	Assessed past caries experience only
Demers et al., 1990	Children-adolescents	Review
Dens, Boute, et al. 1995	14-17 year olds	Not a prediction article. No sensitivities or specificities reported
Disney et al., 1992a	6-10 year olds	Compared dentists with hygienists (North Carolina Study); no new model
Dong, Pearce, et al. 1999	12 year olds	Several variables analyzed separately; no outcome
Drake and Beck, 1992	65+	Discusses models for root fragment prevalence and not root surface caries. Root caries only as a factor for coronal caries prediction
Drake and Beck, 1993	65+	Multiple variables analyzed separately
Drake et al., 1994	65+	Correlation between individual variables and caries
Drake et al., 1997	65+	Root fragments as a consequence of coronal caries not root caries
Federation Dentaire Internationale, 1988		Review
Flinck, Kallestal, et al. 1999	12 year olds	Multiple variables used but Sensitivity and specificity not reported
Forsling et al., 1999	19	Prevalence of caries no prediction/ risk factors
Freeman, Breistein, et al. 1997	5 year olds	Cross-sectional study. Multiple variables analyzed separately with caries. No prediction outcome.
Fure, 1998	60-80 year olds	Multiple variables, but sensitivity and specificity were calculated for independent variables only.
Fure and Zickert, 1990	55, 65, 75 yr. olds	Multiple variables but sensitivity and specificity not reported
Garcia-Closas, Garcia-Closas, et al. 1997	6-15 year olds	Multiple variables but sensitivity and specificity not reported
Granath et al., 1993	5 year olds	Prevalence study (correlation between caries and mutans scores)

Gray et al., 1991	5-7 year olds	Assessed past caries experience only
Gunay, Dmoch-Bockhorn, et al. 1998	3-4 year olds	Several variables correlated separately with caries
Hausen, 1997		Review
Hausen, Karkkainen, et al. 2000	12 year olds	Sensitivity and specificity not reported (no predictive outcome)
[Helfenstein et al., 1991]	7-10 years old	Assessed past caries experience only
Hobdell, Lalloo, et al. 1999	12 year olds	Populational level, not individual. Not a multiple variable prediction model
Hunt et al., 1992	65+	Correlation between caries experience and individual variables
Ismail et al., 1992	6-8 year olds	Prevalence study of carious lesions and education of parents
Ismail, Messer, et al. 1998	7-12 year olds	Multiple variables but sensitivity and specificity not reported
Jalevik, Sjostrom, et al. 1999	17-19 year olds	Retrospective study; past caries experience used as the only risk factor
Kaste et al., 1992	1; 10 year olds	Assessed past caries experience (nursing bottle) only
Khan, Abu-Zeid, et al. 1990	Up to 12 year olds	Multiple factors associated with caries independently
Kidd, 1998		Review
Kingman et al., 1988	10-15 year olds	Assessed microbiological data (SM and LB separately) only
Kinirons & McCabe 1995	Children in nurseries	Multiple variables analyzed separately with caries prevalence.
Klock et al., 1989	14 year olds	Multiple variables correlated separately to caries; sensitivity and specificity calculated only on micro data.
Kohler, Bjarnason, et al. 1995	12 year olds	Caries prevalence study. Only bacteria used as risk factor
Kolmakow, Honkala, et al. 1991	7, 9, 12 year olds	1 variable (dento-facial morphology) associated with caries prevalence
Koroluk, Hoover, et al. 1994	3-5 year olds	Cross-sectional study. Microorganisms and Cariostat (acid production of plaque) were related to caries prevalence separately.
Kruger, Thomson, et al. 1998	15 years old	Sensitivity and specificity not reported (no predictive outcome)
Lai, Seow, et al. 1997	30-52 months old	Multiple variables analyzed separately; risk outcome not clear
Larmas, 1993		Review
Li & Caufield 1995	Birth-3 year olds	Several variables analyzed separately; no caries risk outcome
Li, Wang, et al. 2000	2-3 year olds	Correlation of breastfeeding with either MS or caries (not all 3)
Lin & Tsai 1999	2 year olds	Only 1 risk factor (bottle feeding) was correlated with caries prevalence in cleft lip/palate patients. No prediction outcome
Lith & Grondahl 1992	13 year olds	Used only past caries experience (measured fluoride exposure but did not use it in model)
Litt, Reisine, et al. 1995	4 year olds	Multiple variables, but no sensitivity or specificity reported
Llena-Puy, Montanana-Llorens, et al. 2000	12-13 year olds	Analyzed multiple variables separately
Locker, 1992	50+	Correlation between smoking and caries
Locker et al., 1989	50+	Multiple variables used but sensitivity and specificity not reported
Mandall, McCord, et al. 1998	14-15 year olds	Multiple variables used but sensitivity and specificity not reported
Marques et al., 1994	30-39	Correlation between independent variables and prevalence
Messer 2000	Children	Review
Miura, Araki, et al. 1997	15-64	Correlation of multiple variables with caries. No sensitivity or specificity
Nishimura, Bhuiyan, et al. 1998	Children	Multiple variables; no caries score, no risk assessment of caries
Onozawa, Yasui, et al. 1990	1 month- 3 years old	Sensitivity and specificity not reported (no predictive outcome)
O'Sullivan & Tinanoff 1993	3-5 year olds	Caries location was used as the only predictor for caries risk.
O'Sullivan & Thibodeau 1996	3.8 year olds	No sensitivity or specificity reported (no predictive outcome)
Palenstein Helderman et al., 1989	7 year olds	Assessed past caries experience only
Palin-Palokas et al., 1984	9-10 year old	Correlation between individual variables and caries prevalence
Paunio et al., 1993	3 year olds	Correlation between individual variables and caries prevalence (odds ratio)
Petridou, Athanassouli, et al. 1996	12-17 year olds	Multiple variables, analyzed in a multiple regression model to provide odds ratios for them individually as they correlate with caries prevalence

Pienihakkinen 1988	children	Same as study published in 1987 by same author (this is the thesis)
Pienihakkinen et al., 1987	7-12 year olds	Assessed salivary buffering capacity only
Powell 1998	Children-adults	Review
Powell 1998		Review
Powell et al., 1998	60+	Multiple variables used but sensitivity and specificity not reported
Raadal and Espelid, 1992	Approx.10 year olds	Assessed past caries experience only
Raitio et al., 1996a	13 years old	Multiple variables, analyzed separately
Rajaratnam, Devi, et al. 1995	5+ year olds	Not a prediction study (no sensitivity and specificity)
Ravald and Birkhed, 1991	30-78 year olds	Multiple variables used but sensitivity and specificity calculated separately for each variable
Ravald et al., 1993	47-79 at end of 12 years	Multiple variables used but sensitivity and specificity not reported
Ravald and List, 1998	44-75	Prevalence of root caries in 1° Sjogrens patients vs. Age and sex matched control.
Rodrigues, Watt, et al. 1999	3 year olds	Multiple variables but no sensitivity and specificity reported
Saemundsson, Slade, et al. 1997	5-15 year olds	Cross-sectional study. Multiple variables studied in logistic regression models, but correlated individually with caries prevalence. No prediction outcome
Salonen et al., 1990	≥20	Correlation between independent variables and prevalence
Seow, Amaratunge, et al. 1999	1-3.5 year olds	Multiple variables analyzed separately
Seppa et al., 1989	13 year old	Assessed past caries experience only
Serra, Garcia, et al. 1993	5-14 years old	Multiple variables used but sensitivity and specificity not reported (no predictive outcome)
Sgan-Cohen et al., 1999	25-44	Correlation between caries and independent variables
Shi et al., 1992	12 year olds	Assessed prevalence of mutans streptococci only
Shwartz, Pliskin, et al. 1986	9-16 year olds	Sensitivity and specificity not reported.
Sigurjons, Magnusdottir, et al. 1995	7-59 year olds	Used microorganisms as the only predictor of approximal caries
Soderholm and Birkhed, 1988	Average age 56	Multiple variables analyzed separately
Spak et al., 1994		Comparison of root caries incidence between low and normal salivary flow rate
Splieth & Bernhardt 1999	6-7 year olds	Used multiple variables, but reported sensitivity and specificity are based only on MS scores.
Stamm et al., 1988	7/8 year olds and 10/11 year olds	North Carolina Study I (Preliminary Study). Same data as Abernarthy et al, 1987
Stamm et al., 1991		Review
Stecksen-Blicks, 1987	8, 13 years olds	Sensitivity and specificity not reported (only correlations)
Straetemans, van Loveren, et al. 1998	11 year olds	Caries risk based on MS or LB only; no outcome
Sullivan and Hector, 1995	19-44	Microflora only
Sullivan et al., 1989	5-7 year olds	Correlation between bacteria and caries incidence
Sundh and Emilson, 1989		Incidence of caries in Crohn's disease patients
Tang, Altman, et al. 1997	5 months old-4 years	Multiple variables but no sensitivity or specificity reported
Tenovuo et al., 1990	0.8-3.8 years old	Assessed streptococcus mutans only for prediction
Tenovuo, 1997		Review
ter Pelkwijk et al., 1990	7 years old	Assessed past caries experience only
Tervonen et al., 1991	25-65	Included edentulous patients assigning them as having untreated carious lesions. Logistic regression model: gives Youdens index for predictive value and not sens/ spec.
Thibodeau & O'Sullivan 1999	3.8 year olds	Only SM was used as a risk factor
Thibodeau et al., 1993	3.8 years old	Assessed mutans streptococci variables only in the prediction
Tsubouchi, Yamamoto, et al. 1995	children	Only 1 variable used as predictor (Cariostat-acid production of plaque)
van Houte, 1993		Review
Vanderas 1986	All ages	Review

Vignehsa, Soh, et al. 1991	6-18 year olds	Only 1 variable (disabled) was correlated with caries prevalence. No prediction outcome.
Virtanen, Bloigu, et al. 1997	3-21 years old	Retrospective study. Survival analysis of restorations; restoration in first permanent molar as the only risk factor analyzed.
Weinstein et al, 1996	19 month olds	Epidemiologic study. No prediction outcomes
Wendt & Birkhed 1995	1-3 year olds	Multiple variables (diet, sucking habits) assessed separately; no outcome
Wendt, Hallonsten, et al. 1994	1 year olds	Multiple variables analyzed separately. No prediction outcome.

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